From basic research to the commercial marketplace

W. Richards Adrion
Jaymie Chernoff
Paul Mc Owen
University of Massachusetts
Amherst, MA 01002 USA

Introduction

The academic research environment is changing in response to a number of factors. Chief among these is the increasing role of university researchers, particularly in science and engineering, as originators of new technology in an increasingly competitive world marketplace. How then to maintain the original objectives of university-based research - support of graduate education and faculty scholarship - while encouraging industrial collaboration, entrepreneurship and technology transfer? The solution adopted by the University of Massachusetts, Amherst, is to carefully partition these sometimes conflicting roles using a variety of innovative management and organizational techniques. In this paper, we have chosen to concentrate on some of the activities of the Department of Computer and Information Science (COINS) as representative of the University's increasing commitment to technology creation, development, and transfer. These activities take place in our particular environment - one that is geographically separated from the major industrial centers of Boston and Hartford and is in a state with a history of provincialism in public policy. These factors have influenced the strategies we have developed.

We have divided our discussion into three parts - a history of computing research and technology transfer at the University of Massachusetts, public policy and ethical issues in a state institution, and the changing academic environment and potential conflicts. We conclude with the current status of technology transfer efforts and a description of our successes and remaining challenges.

Background and Motivation

Computers are ubiquitous in the complex systems of our society. We depend on computer technology for educational, medical and social services delivery systems; for information management and communications systems; for manufacturing and design; for defense, transportation, and all aspects of scientific research. Historically, much of computing technology has come out of academic laboratories. The central role of computing technology in national economic competitiveness suggests that this technology must be moved more rapidly from academe to commercial product.

There are several barriers within the discipline to successful technology development and transfer in academic computing research laboratories. As computing technology grows more

complex and as advances come at an astounding pace, computer scientists are justly criticized for continuing to conduct basic research in relatively simple laboratory environments, ignoring issues raised by the growing complexity of commercial and social applications. Computers and computation systems are certainly objects of research, but they must also be viewed as components of the social and economic mechanisms of our society, vital to our competitiveness and productivity. Academic computer science has too often "tossed its research over the fence" for others to develop and commercialize - and, unfortunately, too often for others to ignore.

In addition to discipline-based barriers, there are growing concerns throughout U.S. academic science and engineering over ethical, scientific fraud and intellectual property issues. These concerns have intensified recently, particularly in the biotechnology and medical sciences disciplines.

Thus, given our particular geographical and political environment, the traditional barriers within the discipline, and the ethical and ownership concerns, the University of Massachusetts has taken a three-pronged approach to its computing research programs. The University expanded and strengthened its traditional programs for graduate computer science education and research; developed several mechanisms for industrial cooperation and collaboration; and developed policy and incentives for entrepreneurship and technology transfer.

Over the last twenty years, the University has developed, in COINS, a first class program of basic research and computer science education. This program ranks among the top U.S. departments by many measures - quality of instruction, quality of the faculty, and level of research activity. For example, COINS was designated by the U.S. Department of Defense as one of two national "Centers of Excellence in Artificial Intelligence." COINS research is necessarily long-term and fundamental - its traditional strengths in artificial intelligence and computing systems are in highly experimental areas. Research results find their way to other universities, government laboratories and industry research centers through the open literature, scientific conferences and the individual researcher's interactions and collaborations. It is is essential to maintain this research base - allowing individual researchers to pursue problems purely from intellectual motivation and free from short-term commercial or other interests.

The other two objectives of the University's computing research programs - stimulating new basic computing research in the *context* of significant social systems and transferring the technologies developed rapidly to the marketplace - required the creation of a host of new and innovative mechanisms. To address the former objective, the University has established a center for industry-university collaboration on "applications-driven" research, a plan for an on-campus industrial park, and other incentives for industrial collaboration. Secondly, the University founded a applied research-institute and development center to provide a pipeline for faculty entrepreneurial efforts, an environment for nurturing spin-offs, and a mechanism for industry to commercialize basic research results through both open

and proprietary relationships. In conjunction with this program, the University has had to address important policy issues in the areas of faculty/staff entrepreneurship, patents, intellectual property, reward systems, ethics and scientific fraud and misrepresentation.

The Center for Research on Real-Time, Intelligent Computation in Complex Systems (CRICCS) represents an innovative approach to collaborative university-industry research, education, and outreach and a novel instrument for technology transfer. CRICCS is driven by a vision of computing in the next century, in which computers, robots, and humans work cooperatively in large organizations. What differentiates CRICCS from other centers is its unique research paradigm. Basic research is carried out in the *context* of real applications provided to the center by its private-sector partners. These application domains are generalized within CRICCS and often physically modeled to serve as testbeds for basic research on the associated scientific issues. Problem solutions to these generic models are applied to the original application domains with the participation of industrial scientists and engineers. This provides both technology transfer and feedback to basic research process. At the next stage, these results are applied to similar application domains with different parameters to test the generality of the results and the models. For example, Rockwell has provided a real-time materials processing control application which has been physically modeled in the University's Polymer Science and Chemical Engineering laboratories. This serves as a testbed for the development of real-time, intelligent control software and systems, sensors and effector devices. The results from this research is being moved back into Rockwell's application domain by Rockwell scientists collaborating with COINS, Polymer Science and Chemical Engineering faculty, students and technical staff. In parallel, these results are being extended to a medical monitoring domain in collaboration with Stanford computer scientists and Bay State Medical Center researchers, and to an avionics application in collaboration with FMC and Texas Instruments scientists and engineers.

We have identified two initial focal areas, or contexts, for CRICCS research - the complex process control and management domain described above and domains employing cooperating, interactive robotic systems. In this second area, our emphasis will be on cooperating robotic devices with multi-dimensional sensory and effector networks operating in environments hostile to or difficult for human activities, and is in collaboration with the University of Rochester, General Electric, General Dynamics, GTE and Digital Equipment. While COINS researchers have considerable experience with these technologies, to address the social and economic problems facing this Nation and the world community, we must conduct our research in the context of large goals and large applications that are representative of the complex, computer-based systems on which our society depends. CRICCS comprises the right team and offers the right environment to make significant progress toward these goals. In addition, CRICCS has companion programs of education and outreach involving the above mentioned universities and industries, six traditional liberal arts colleges (Amherst, Hampshire, Mt. Holyoke, Smith, Wellesley and Williams) and the Massachusetts State System of

Higher Education, designed to attract more young scientists to the problems addressed by CRICCS and to increase the trained labor force in these applications domains.

The Center will be located in a new, on-campus industrial research park which will house CRICCS, technical staff from the industrial partners, the applied research institute, other industry laboratories and various University-spin-off firms. This park shows great promise to provide the appropriate environment for achieving the objectives of increased industry-university interaction and collaboration, specialized educational opportunities and technology transfer.

CRICCS and the new industrial park serve as a bridge to the third component of the University's programs in computing research. To complement COINS and CRICCS, we have formed a private corporation, the Applied Computing Systems Institute Of Massachusetts (ACSIOM) to be a technology transfer agent for COINS and CRICCS technologies. As an independent corporation under the control of the University, ACSIOM is able to enter into close working relationships with industry, to develop patents and copyrights, to establish and nurture entrepreneurial companies to commercialize technology, and to offer training and consulting services. ACSIOM serves as the applied research compliment to COINS and CRICCS research.

One of the chief motivations for creating ACSIOM was the geographic location of the University – two hours from Boston and the "Route 128"- and Cambridge-based industrial activities. The natural opportunities for industrial collaboration and interchange that exist in Boston, Cambridge, and Route 128 areas do not exist in Western Massachusetts. This barrier has presented an opportunity to create a new model - a "collaboratory," specifically designed for the effective use of the results of basic research to solve long-term industrial problems and to create commercial opportunities. ACSIOM represents a necessary mechanism for dealing with other companies, proprietary products, and commercial markets in way which avoids interfering with the public educational mission of the University and its need to maintain a free and open intellectual environment. While faculty, research staff, and students move around at different times among the three organizations, the lines are carefully drawn through established policy to insure that each organization can address its mission effectively.

A Tradition of Computing Research and Technology Transfer

The University of Massachusetts founded the Department of Computer and Information Science in the early 1970's. The initial emphasis of the department was on pioneering research on neural networks and computer vision. In the late 1970's through the early 1980's, the artificial intelligence programs in the department were expanded to include natural language, expert systems, machine learning, case-based reasoning and distributed AI. During the same period, the department expanded its systems research programs in software engineering, programming languages, databases, operating systems, networking and real-time systems. In the mid 1980's, COINS added major programs in robotics, architecture, intelligent computer-

aided instruction and computing theory. Today, COINS represents a comprehensive program of research and education in computer science.

Even before the concept of ACSIOM was developed, the University has established a history of commercial development, technology transfer and entrepreneural activity in computing. In the early 1980's, VI Corporation was established to market a graphical software environment which provides flexible visualization of real time data streams. This product, Dataviews, a prototype of which was originally developed by the COINS Visions Laboratory, has been used by NASA to monitor space shuttle missions and the Hubble telescope. A more recent spin-off of the Visions Laboratory, Amerinex Artificial Intelligence (AAI), is marketing another software system, KBVision, and carrying out applied research for the Department of Defense.

Over the past year, ACSIOM has assisted with the incorporation of four new start-ups. ACSIOM Labs, Inc. was established as a consulting/contracting arm for ACSIOM and is currently involved with McDonnell Douglas Aircraft in a government-funded program of research on real-time systems and real-time AI for aeronautics. Top Level Inc. was founded to commercialize a parallel implementation of Common LISP language (PICCL) developed under an NSF Coordinated Experimental Research center in COINS. Both PICCL and the commercial system, TopCL, realize significant performance improvements on Sequent, Encore, and other parallel machines. TopCL is currently being ported to a new generation of multiprocessor workstations under a cooperative agreement with COINS and Top Level.

In the last year, Blackboard Technology Group was formed and is commercializing and licensing the Generic Blackboard System (GBB), a highly tuned environment for creating high performance distributed AI applications. GBB was developed initially in COINS under industrial and Government funding. The "research" version is now supported by the industrially-funded GBB Consortium in ACSIOM Laboratories, in collaboration with COINS, and is distributed at nominal cost to university and industrial laboratories. Experience has shown that industries will first "try out" GBB in the research version, then move to the BTG commercial GBB for their applications. Corporations purchasing GBB from BTG remain enthusiastic supporters of the GBB Consortium providing a continuum of support from basic research through commercial application. Interestly, both BTG and the Consortium are developing parallel versions of GBB employing TopCL as the implementation language through cooperative agreements with BTG, Top Level and the University.

The newest company to be spun off from COINS is Specular International. Specular is marketing high quality animation creation and ray-tracing software for MacIntosh environments. This software provides spectacular 3D animation effects at a fraction of the cost of some other packages and continues to be the subject of research in the COINS Intelligent Computer-Aided Instruction Laboratory. Other intelligent tutoring software from this laboratory has been licensed to Apple Computer and Texas Instruments.

In addition to these activities, COINS has had a long history of close industrial relation-

ships. Many of these have been with Digital Equipment Corporation due to geographical proximity and the significant number of University graduates who have joined Digital. Last year Digital and the University established Project Pilgrim, a $6M project involving COINS, the University College of Engineering and Digital technical staff. Project Pilgrim will provide the University with an integrated research and educational computing environment of distributed, multi-manufacturer workstations and central servers with a common user interface and network services. As the largest university-based project of Digital since Project Athena, Project Pilgrim is the first system to extend the open systems concepts to heterogeneous operating systems as well as hardware and will integrate various Unix-, VMS- and Lisp-based environments. Project Pilgrim has attracted considerable commercial interest and we are negotiating with several companies and institutions to join the Project, including Sun Microsystems, Sequent, Hewlett-Packard/Apollo, Bull and the Open Systems Foundation.

Several industrial relationships have developed around issues in parallel and distributed computing. The Visions Laboratory proposed a massively parallel architecture for machine vision - the Image Understanding Architecture (IUA). Simulated benchmarks showed the IUA orders of magnitude faster than any other existing or proposed machine. The IUA is the first machine capable of sustaining real-time image processing at video frame rates. Recognizing the potential of the IUA, DARPA several years ago funded a collaborative project between COINS and Hughes Research to build a prototype IUA. The machine is being delivered and tested this year. Preliminary performance studies were so impressive that DARPA and General Dynamics are funding an expansion of this activity under a cooperative agreement being negotiated with COINS, Hughes, AAI and Top Level to produce the machine and associated software systems.

Other activities in parallel and distributed computing include the Sequent, Texas Instruments and COINS work which led to GBB and PICCL. A recent cooperative research program, with funding from Digital, Thinking Machines and NSF, to exploit the capabilities of the Connection Machine for computer vision, information retrieval, parallel computing environments has led to the installation in COINS of a 4096-processor Connection Machine. A project on software engineering environments - the Arcadia Consortium involving the University, California-Irvine, Berkeley, Stanford, Colorado, TRW, Aerospace and Incremental Systems - has been underway for three years and is producing a framework and platforms for producing distributed and real-time software and systems.

Policy Issues in a Public Institution

In order for ACSIOM to accomplish its goals of technology transfer and applications-driven industry interaction, the University had to address a number of policy issues. Some of the issues are common to most major research universities in the current environment where ideas may have substantial economic value. The ownership of non-patentable ideas, the sharing of risks and rewards of technology transfer, the academic staff member's setting

of research priorities and his or her allocation of time and intellectual energy were issues for which existing policies were inadequate.

Additional obstacles face the public university. Many states are or were in the position of Massachusetts, which has a state conflict-of-interests statute, General Laws 268A. A legitimate means of protecting the state from graft and corruption when applied to state agency employees who are severely circumscribed in their dealings with the private sector, it is nevertheless a sledge-hammer approach to academic conflict of interest. Computer science faculty today are encouraged by state and federal policy makers to engage in meaningful interactions with industrial partners and to consider the benefits to society of the transfer of their technology. These conflicting expectations diminish the probability of success for public institutions.

A prerequisite to ACSIOM's success was an infrastructure of policies and expectations which grappled with the inevitability of tension between the open academic environment and proprietary interests. This did not initially exist at the state or campus level and much of the organizational history of ACSIOM has been the story of the University's coming to terms with the need to develop policies that would recognize and manage conflict rather than banish it.

Considerable progress has been made. A campus-wide Committee on Entrepreneurship, composed of two deans, several entrepreneurial faculty, more traditional humanities faculty, and industry relations staff, and chaired by the deputy provost, sorted through and clarified the issues. A preliminary survey of other public research universities revealed that several had sought legislative remedies to limit the application of state conflict of interest regulations to university faculty, if sufficient disclosure and monitoring were in place on the campus. The final report on entrepreneurship called for the establishment of a formal conflict of interest policy. This has been drafted and is circulating among campus interest groups. When adopted, this process of disclosing, monitoring, and remediating conflict will resolve the ambiguity of the technology transfer activities of individual faculty members. Conversations with state legislators and the Ethics Commission staff (charged with enforcing the state's policy) have confirmed the acceptability of our actions.

The question of ownership of software spun off from university research has been resolved by a new software policy. Caught for a time between the perspective of software as an intellectual product similar to a textbook (traditionally the sole property of the author/faculty member) or more like a patentable device (where ownership resides with the University but royalties are shared with the inventor/faculty member), University policy has taken the latter view. This has been a boon to ACSIOM in two ways: it provides a clear policy for compensating the inventor, and it encourages faculty to license their software through ACSIOM since their ability to go out on their own is more limited.

Not all of the legal issues had to be addressed at the University level. A critical first decision made by the ACSIOM Board of Directors, was whether to conceive of the corporation

as a strictly private body, or as a corporate "instrumentality of the University (state)." Either way, ACSIOM would be working closely with the University (the state) and academic personnel (state employees), and each choice presented different forms of conflict according to state policy. The board chose to be viewed as a state-related corporation because that reflected its real purpose and, significantly, because that definition allowed the board to limit its membership to University personnel. Issues of faculty control versus the desire for outside expertise are important ones for any university technology transfer entity to weigh in its initial development.

Another corporate instrumentality of the University, the University Foundation, will be critical to ACSIOM's ability to provide the physical space for its own growth as well as for the spin-off companies and industrial partners attracted to CRICCS. This is especially important in the University's rural environment where there are no natural incubators such as the 19th century factories found in many New England industrial centers. Like ACSIOM, the University Foundation is a private corporation which can buy land, borrow funds, and own real estate. The development of University owned land for academically-related commercial purposes will only be possible by first conveying that land to the Foundation. This has been the mechanism adopted by many universities in developing research parks.

This is, nevertheless, a lengthy process, and in the interim, the University has encouraged private developers to create industrial land capacity in the region. The Hadley University Park is the principal such development. It is only 2 1/2 miles from campus and will be linked by fare-free shuttle bus and telecommunications lines.

Dealing with a Changing Academic Research Environment

In an ideal situation, the three pronged approach we have described - COINS, CRICCS and ACSIOM - would address all of the objectives we have set forth for computing research at the University of Massachusetts. We would be able to maintain our excellent academic research and educational programs, we would be able to carry out our research both along traditional lines and in the context of significant "real-world" problems, and we would be able to transfer our technology through industry collaboration and direct commercialization. And, we would be able to carry out all of these activities in a way that benefits society, the institution and the individuals. There are significant barriers to overcome, however. Among these are the traditional reward system within the University, the perception of society about the role of a public university, the potential for corrupting one of more of the objectives and the self interests of the participants - be they individual researchers, the university, or industry.

One of the reasons for establishing ASCIOM was that it was growing increasingly difficult to maintain and distribute software and systems within the traditional university setting. Faculty are rewarded, i.e., given raises, promotions, etc., based on research, teaching and service, not for producing and maintaining commercial grade software. Technical staff in an

university are attracted to the environment by the opportunity to work on research. Salaries for technical staff in universities usually are not commensurate with industry. Universities do not usually have staffs competent in the management and development of releases, versions, bug reports, engineering changes, field support, manuals, documentation, marketing materials, etc. associated with software distribution and maintenance. The technical support "culture" in ACSIOM is being developed to be much more similar to industry than to academe. Faculty, staff and students, when they are employed by ACSIOM *for duties not expected* in their university roles can receive additional compensation for their efforts - which provides an incentive, absent in the University, for paying more attention to the details required to make research software more portable and robust.

The existence of ASCIOM introduces new issues. Should faculty, staff, or students be required to work for ACSIOM or to develop their research prototypes in a form more easily transferred to ACSIOM? The answer at the University of Massachusetts is a definite *no* - interactions with ACSIOM are entirely voluntary. No credit is given for work done nor penalties given for work not done in conjunction with ACSIOM beyond what that work might do to enhance the reputation of the individual. In this sense, collaboration with ACSIOM is treated in much the way that independent consulting is treated. Who benefits from the "profits" accrued from software and systems commercialized by ACSIOM or its spin-offs? Essentially this is governed by the policies described above. Patent and intellectual property policies are defined by the University. Agreements are being negotiated with the State ethics commission concerning compensation. Disputes are settled using the University's policy on misconduct.

There are significant issues of proprietary interests in both ACSIOM and CRICCS. In CRICCS, the paradigm of bringing industrial applications into the center coupled with the participation of many industrial partners raises problems. The solution is to partition projects within CRICCS and to develop cooperative agreements and disclosure arrangements among all participants *prior* to beginning a specific project. All research results of CRICCS are open and available to all participants in CRICCS and the scientific community. The intent is to protect only the proprietary systems contributed by the participants, not the generalizations, extensions or revisions resulting from the collaborative research. ACSIOM offers a mechanism for researchers in CRICCS to commercialize new or extend proprietary systems where access can be limited. The boundary is clearly defined, however. Nothing of a proprietary nature can be developed within CRICCS. Again the University policies on ethics, misconduct, openness in research, contracts, prior publication review, patents and intellectual property apply. The University is dedicated to open and free research - and CRICCS is a part of the University. Our experience is that industry is quite willing to participate within CRICCS on these terms.

Conclusions

In attempting to evaluate the relative success of technology transfer efforts across the COINS/CRICCS/ACSIOM continuum, one should consider the two major goals of this effort - to enhance the long-term basic research program of COINS and to stimulate the economy by transferring to industry new needed technologies as rapidly and effectively as possible. In these terms, the triad has been accomplishing its objectives. Useful software has been licensed to major corporations, new start-ups have spun off to distribute and commercialize the products of our research. Dozens of new jobs have been created in proximity to the University. Tens of thousands of dollars have been contributed to the University by ACSIOM in its first year for the support of research assistantships for graduate students in COINS. The feedback to COINS from the commercialization process is extremely useful to the basic research program.

Another consideration for the evaluation of relative success should be the scope of activities. Compared to the COINS/CRICCS program, the scope of ACSIOM activities, today, is rather small. With the right model to work with and the right institutional/corporate mechanisms in place, the scope of these activities should be expanded and the efforts accelerated. The funding required for this has not been and is not likely to be forthcoming from either the University or the banking community. While the University is supportive, its primary mission is not seen as supporting industry. Local banks are extremely conservative and while they may invest, with security, in successful start-ups, later in the development curve, they are unlikely to support incubators and early development efforts. Funding is possible from two sources: a government partnership, or high-risk investment partners. The latter could be either individual investors or corporate partners. The next measure of success with these efforts will be related to the ability to raise significant investment capital without sacrificing control of the overall mission.

With respect to the proprietary interests of individuals and institutions, we have been generally successful. As noted, corporations have been willing to participate with COINS, CRICCS and ACSIOM within the ground rules established. The University has been willing to allow commercialization with a modest return based on the perceived level of investment of the institution in the work. This ranges from no fees when the work has clearly been outside of the University to major compensation, governed by the patent and intellectual property policies, when significant University resources have been involved. The most difficult problem has been to maintain openness is the face of potentially large financial rewards. To date, we have been able to handle this on a case-by-case basis, but we continue to struggle with the development of a policy which will govern this complex issue. Similarly and related is the issue of ownership is a highly interactive and collaborative environment. Again, we have dealt with this successfully to date and we do have the University misconduct procedures as a last resort, but it is another area where we are attempting to develop a reasonable policy.